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The Relative Cost of Making Logs from Small and Large Timber

BY

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THE RELATIVE COST OF MAKING LOGS FROM SMALL AND LARGE TIMBER

By DONALD BRUCE

The stop watch has for many years been used by efficiency engineers in analyzing industrial operations along many lines. Few time studies of logging, however, have ever been made and of less have the results been made available through publication. The study which is to be partly described in this bulletin was made on the logging operations of three representative lumber companies of the Sierra Nevada, each operating with modern machinery efficiently handled. One of the three is located in conditions typical of the east side of the Sierra, one in those of the west side, while the third is intermediate. Each of the three companies coöperated cordially and extended every facility for work. Mr. Swift Berry, Logging Engineer of the U. S. Forest Service at the time of the study, also gave valuable assistance in initiating it.

The study was not designed to prove or disprove any theory, nor even to ascertain any specific facts. It was intended rather as a general investigation of the factors affecting the cost of logging. Yet while these factors were many, the one outstanding result of the work was a proof of the excessive cost of logging small timber as compared to large, when methods and machinery adapted to the latter are used.

The present bulletin restricts itself entirely to log making, i.e., falling, limbing, marking and bucking. The following pages will show that *it costs three times as much per M. B. M. to make logs from 18-inch as from 48-inch trees, and that below that diameter the costs undoubtedly rise rapidly with each further decrease in size.*

Table I and figure I summarize the results obtained. In the figure it will be noted that not only the total cost but that of three out of four of the individual operations fall rapidly as diameters increase up to about 40 inches. Limbing alone is an exception and its relative importance is small. Bucking remains practically constant for the largest sizes although its decrease for small sizes is most rapid of all. No figures for trees under 18 inches in diameter were available, but the trend of the curves is convincing evidence that even higher costs would be encountered for these smaller sizes.

TABLE I

EFFECT OF TREE DIAMETER ON COST OF LOG MAKING

Diameter breast high	Cost per M. B. M. Falling	Marking	Limbing	Bucking	Total
18	$0.77	$0.18	$0.08	$1.02	$2.05
20	.67	.17	.08	.84	1.76
22	.60	.17	.09	.68	1.54
24	.55	.16	.10	.58	1.39
26	.50	.15	.12	.50	1.27
28	.45	.13	.13	.44	1.15
30	.41	.12	.14	.40	1.07
32	.37	.10	.14	.38	.99
34	.34	.09	.15	.36	.94
36	.30	.08	.15	.35	.88
38	.27	.07	.14	.34	.82
40	.25	.06	.14	.33	.78
42	.23	.05	.13	.33	.74
44	.21	.04	.12	.33	.70
46	.20	.04	.11	.33	.68
48	.19	.03	.11	.33	.66

Wage Scale Used—	Per day
Fallers	$5.00
Markers	4.75
Limbers	4.25
Buckers, steam saw, head	5.00
Buckers, steam saw, second	4.25
Buckers, hand	4.50

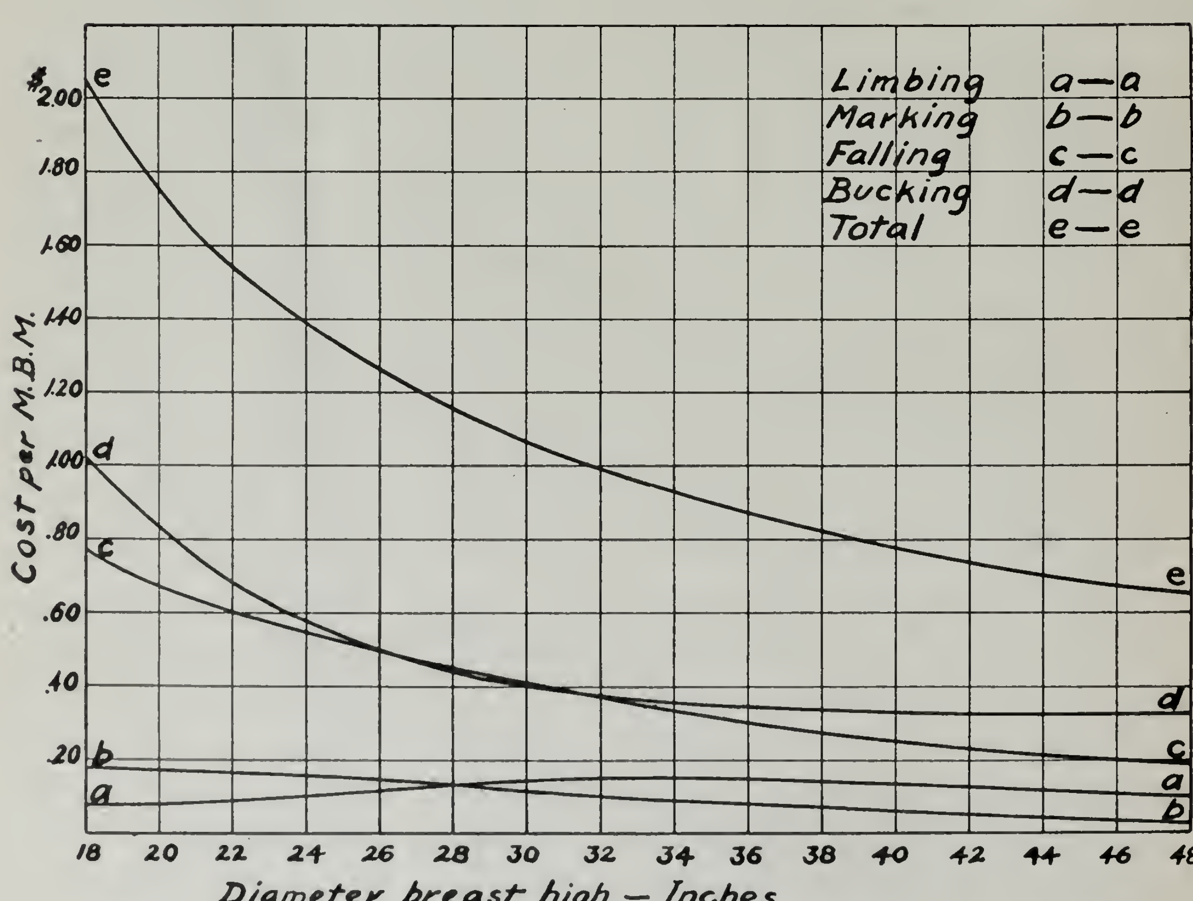

Fig. 1.—Effect of tree diameter on cost per M. B. M. of log making.

During periods of rapidly changing wage scales, cost figures in dollars and cents are apt to be misleading. On this account costs were reckoned in minutes of labor throughout this study except in the foregoing table where time was translated into money at the wage scale indicated beneath. All wages are for a nominal 10-hour day, but the value of a minute of time was calculated on the basis of the actual number of minutes worked per day on the operations studied, a somewhat lower figure.

The data upon which the conclusions were based will now be described, together with the method of reaching them. Falling, marking, limbing and bucking will each be treated separately.

FALLING

The study included stop-watch observations on the falling of 113 trees, having a scale of 177 M. B. M., gross, and 151 M. B. M., net. Measurements of diameter and volume of each tree and the exact time for each of the following items was recorded:

"Walking" (from tree to tree), "Swamping," "planning" (looking over ground, deciding on direction of fall, etc.), "undercutting with saw," "undercutting with axe," "barking," "preparing to saw" (including preliminary oiling of saw), "sawing," "wedging," "tool fitting," "gathering tools" (preparatory to moving to next tree to be falled), "whistle" (interval between the close of work and the whistle which marked the end of day for yarders), "delays" (each sort of delay being separately recorded).

Table II is a summary of the results obtained and shows not only the total time spent on each of the above listed items, but also the average time for each item per tree and the per cent of the total time. The times recorded are man-minutes and not crew-minutes.

Of the items timed it is obvious that some will be independent of tree diameter but will in the long run (though varying widely in individual cases) tend to approach a constant average per tree. "Walking" and "gathering tools" are clearly of this nature, and it is therefore reasonable to charge to each tree the average for these two items given in Table II, totaling 1.69 minutes per tree. This figure is of course independent of species also.

A large number of other items will obviously vary with the diameter of the tree. Some, such as "sawing," "wedging," etc., were unquestionably of this class while in the case of others, such as "swamping," an examination of the data was necessary to permit a decision. The items finally included in this class are as follows:

"Planning," "undercutting," "barking," "preparing to saw," "sawing," "wedging," certain "delays," such as "oiling," "setting spring boards," etc.

TABLE II

SUMMARY OF TIME REQUIRED TO FALL 113 TREES

Operation	Average Time Minutes per Tree,	Per cent of Time
Walking	0.96	1.91
Swamping	1.48	2.96
Planning	2.66	5.33
Undercutting—saw	3.02	6.06
Undercutting—axe	7.53	15.13
Barking	3.93	7.91
Preparing to saw	2.16	4.34
Sawing	8.42	16.90
Wedging	2.33	4.68
Tool Fitting	0.50	1.01
Resting	12.97	26.05
Gathering Tools	0.73	1.45
Whistle	0.51	1.02
Delays	2.60	5.25
TOTALS	49.80	100.00

The 113 trees observed were about half white fir, and half western yellow pine. As a preliminary analysis showed that the differences between the times for trees of the same diameter for the two species was almost imperceptible, the two were averaged together at first, leaving until later the more precise determination of the effect of species. Table III shows the actual averages obtained for different size classes and the most probable true values for the same as adjusted graphically.

TABLE III

INFLUENCE OF DIAMETER ON TIME OF ALL FALLING ITEMS DIRECTLY AFFECTED THEREBY

Diameter Class. Inches	Average time for items varying with diameter. Minutes per tree	Same adjusted graphically. Minutes per tree	Basis Number Trees
20–24	23.4	22.5	16
25–29	24.9	26.8	32
30–34	33.5	31.7	27
35–39	36.9	37.3	23
40–44	44.8	45.8	9
45–49	59.7	58.4	5
			112*

The effect of species was now studied, and it was found that the western yellow pine averaged only .71 of 1 per cent less than the foregoing figures, while white fir averaged .61 of one per cent more. As it seemed best to express all results in terms of a single species, western yellow pine, the foregoing deduction (.71%) was made.

* One 53-inch tree was discarded.

The remaining time items are such as "resting" and other general delays which can most properly be handled by prorating them against the other times already discussed. Since they amount to 35.9% of the whole time they can be cared for by adding to the other items,

$$\frac{.359}{1.000-.359}=56\%.$$

Table IV shows the final computation of the time chargeable to trees of various diameters, and of the time-cost per M. B. M. therefor.

TABLE IV

TIME COST OF FALLING AS AFFECTED BY TREE DIAMETER

Diameter Breast High. Inches	Time per tree—minutes: A Items varying with diameter	B Items constant per tree	A+B	Total (A + B multiplied by 1.56 to prorate all other items)	Average gross volume per tree, M. B. M.	Time per M. B. M. gross scale, Minutes
18	18.2	1.7	19.9	31.0	.40	77.5
20	19.4	1.7	21.1	32.9	.50	65.8
22	20.8	1.7	22.5	35.1	.59	59.5
24	22.2	1.7	23.9	37.3	.68	54.8
26	23.8	1.7	25.5	39.8	.79	50.3
28	25.3	1.7	27.0	42.1	.93	45.2
30	27.1	1.7	28.8	44.9	1.11	40.5
32	29.1	1.7	30.8	48.0	1.31	37.6
34	31.4	1.7	33.1	51.6	1.54	33.5
36	33.8	1.7	35.5	55.3	1.86	29.7
38	36.6	1.7	38.3	59.7	2.21	27.0
40	40.0	1.7	41.7	65.0	2.63	24.7
42	44.1	1.7	45.8	71.5	3.14	22.8
44	49.1	1.7	50.8	79.3	3.78	21.0
46	55.8	1.7	57.5	89.7	4.54	19.7
48	60.6	1.7	62.3	97.2	5.10	19.1

The second column is taken from the same curve as column 3 of Table III but now read for every 2 inch increase in diameter. The third is from Table II. The fourth is the sum of the second and third. The fifth is obtained by multiplying the fourth by 1.56, to allow for the time of resting and delays. Column 6 is taken from a local volume table in preparing which the average volumes of trees of different diameters, as scaled on the logging operation studied, were computed. The final column is, then, column 5 divided by column 6.

Column 2 of the original table I was now derived directly therefrom by allowing for cull (7.4% of the gross volume) and then multiplying by the cost of a minute's time.

MARKING

The marking of the trees into proper lengths for bucking into logs is not an important operation from the standpoint of cost. Observations were therefore made on but 51 trees which scaled 115 M. B. M.

gross and 100 M. B. M. net, of which 44 were western yellow pine. The log lengths marked averaged slightly over 16 feet. Table V summarizes the data obtained.

TABLE V

SUMMARY OF TIME REQUIRED TO MARK 51 TREES

Operation	Average Time per Tree—Minutes	Per cent of Total Time
Walking	.60	5.46
Marking	6.20	56.63
Resting	4.15	37.91
Totals	10.95	100.00

As in the case of falling, the time items fall into three classes, those independent of tree sizes (in this case ''walking''), those varying directly with it (''marking''), and those which must be prorated against all other items (''resting''). The ''marking'' proper, however, is more closely correlated with tree height than with diameter, and this relation was investigated first.

Some of the trees had been limbed previous to marking and some had not; as has already been stated two species were observed. It was of course necessary to reduce the measurements to a common basis. The question of species was handled by omitting the white firs, which were few in number. Using only the yellow pine data, a preliminary study showed that trees which had not previously been limbed averaged about 13.5% longer in marking time than those which had. The times for the former trees were therefore reduced by this per cent and then averaged with those for the latter. The results are given in Table VI which also shows the calculations for the inclusion of the time of ''walking'' and of ''resting.''

TABLE VI

TIME COST OF MARKING TREES NOT PREVIOUSLY LIMBED AS AFFECTED BY TREE HEIGHT

Height in Logs	Number of Trees observed	A—Marking: Average Time, Minutes	A—Marking: Same, Curved	B—Walking Average Time per Tree—Minutes	A+B	Total including resting. (A+B) ×1.61
2	1	2.9	3.1	.6	3.7	5.9
3	6	4.5	4.6	.6	5.2	8.4
4	22	6.2	6.1	.6	6.7	10.8
5	10	7.0	7.6	.6	8.2	13.3
6	5	10.2	9.2	.6	9.8	15.7

A recalculation now showed that previous limbing reduced the ''marking'' time by 10 per cent.

While to express marking time in terms of height is the most logical procedure it is impossible to correlate the figures thus compiled with

those already calculated for falling. It is therefore desirable to translate them into terms of diameter; Table VII shows how this may be done.

TABLE VII

TIME COST OF MARKING AS AFFECTED BY DIAMETER

Diameter Breast High Inches	Average Merchantable Height Logs (16 ft.)	Time per Tree—Minutes	Average Gross Volume per Tree M. B. M.	Time per M. B. M. Gross Scale Minutes
18	2.8	7.9	.40	19.7
20	3.4	9.3	.50	18.6
22	3.9	10.6	.59	18.0
24	4.3	11.6	.68	17.1
26	4.7	12.6	.79	15.9
28	4.9	13.0	.93	14.0
30	5.1	13.5	1.11	12.2
32	5.3	14.0	1.31	10.7
34	5.5	14.5	1.54	9.4
36	5.7	15.0	1.86	8.1
38	5.9	15.5	2.21	7.0
40	6.1	15.9	2.63	6.0
42	6.3	16.4	3.14	5.2
44	6.5	16.9	3.78	4.5
46	6.7	17.5	4.54	3.9
48	7.0	18.2	5.10	3.6

Column 2 of this table was derived from a curve showing the merchantable height of trees of various diameters, the basis for which was all the trees measured on the operation located on the east side of the Sierra, both in connection with falling, marking and limbing. Column 3 is derived from the final column of Table VI, the values being interpolated and exterpolated to correspond to the exact heights given in Column 2. Column 4 is obtained from the volume table already described on page 321. Column 5 is column 3 divided by column 4. This final column was the basis for column 3 of Table I, allowance first being made for cull, amounting to 13.2%, and the modified times then being multiplied by the cost per minute based on the wage stated.

It will readily be seen that Table VII should not be expected to apply accurately to any operation other than that from which the data were obtained. The relation between height and diameter, that between volume and diameter, and the cull percentage might well all be different in another region. Furthermore, the high percentage of time used for resting (Table V), indicates that the marker was not kept very busy by the organization studied. All these factors might modify the actual costs under different circumstances, but should not affect materially the relation between the costs for large trees and small.

LIMBING

Observations were made on the limbing done by three different workmen of 125 trees, having a scale of 210 M. B. M. gross, and 180 M. B. M. net. Table VIII summarizes the results.

TABLE VIII

Summary of Time Required to Limb 125 Trees

Operation	Average Time per Tree—Minutes	Per cent of Total Time
Waiting for fallers	8.17	33.58
Walking	.89	3.65
Preparing to work	.06	.23
Chopping	11.42	46.97
Resting	3.58	14.72
Miscellaneous	.21	.85
Totals	24.33	100.00

The most striking figures in this summary are the percentages of time spent in waiting for fallers and in resting, which together amount to 48 per cent of the total. It is obvious that the men were not kept very busy and that the costs calculated on the basis of their work may prove abnormally high. As in the case of marking however, the *relative* costs for different sizes of trees should be reliable.

Using the same grouping as in the previous cases it will readily be seen that "chopping" should vary with the diameter of the tree, "walking" and "preparing to work" should be treated as a constant time per tree, while the remaining items may be prorated. Table IX shows the computations by which the time cost per M. B. M. are worked out.

Column A is obtained by graphically averaging the actual times spent in chopping on trees of different diameters, using only the western yellow pine, 71 in number. Column B is taken directly from Table VIII. The next column adds these two items together, while the fifth prorates the remaining items. Column 6 is taken from the volume table already described, and column 7 is derived by dividing column 5 by column 6.

From this final column, column 4 of Table I was derived by allowing for cull (7.5% in the case of the yellow pine limbed) and multiplying by the cost of a minute's time.

TABLE IX

TIME COST OF LIMBING AS AFFECTED BY TREE DIAMETER

Diameter Breast High—Inches	Time per Tree, Minutes: A Chopping	B Walking and Preparing	A+B	Total (A+B multiplied by 1.966 to prorate other items)	Average gross volume per Tree M. B. M.	Time per M. B. M. Gross Scale Minutes
18	.9	.9	1.8	3.5	.40	8.7
20	1.4	.9	2.3	4.5	.50	9.0
22	2.2	.9	3.1	6.1	.59	10.3
24	3.3	.9	4.2	8.3	.68	12.2
26	4.6	.9	5.6	11.0	.79	13.9
28	6.4	.9	7.3	14.3	.93	15.4
30	8.2	.9	9.1	17.9	1.11	16.1
32	10.3	.9	11.2	22.0	1.31	16.8
34	12.7	.9	13.6	26.7	1.54	17.3
36	15.2	.9	16.1	31.6	1.86	17.0
38	17.8	.9	18.7	36.8	2.21	16.7
40	20.6	.9	21.5	42.3	2.63	16.1
42	23.5	.9	24.4	48.0	3.14	15.3
44	26.6	.9	27.5	54.0	3.78	14.3
46	29.7	.9	30.6	60.2	4.54	13.2
48	33.0	.9	33.9	66.6	5.10	13.1

The fact that medium-size trees are more expensive to limb than either very small or very large ones can probably be explained by the fact that in the former the limbs, while numerous, are light and easily removed while the latter have their large limbs concentrated at the top above the merchantable portion of the trunk.

BUCKING

This is the most important of the operations of log making from the standpoint of cost, and was therefore studied more exhaustively than the others. In both the camps where observations were made, trees were bucked into long lengths in the woods by hand, yarded in this form, and then further bucked into short car lengths by steam saw in a chute at the landing. Studies were therefore made of both hand bucking and steam-saw bucking.

HAND BUCKING

Times were recorded for 346 cuts, made by five different laborers, and with a scale of 432 M. B. M., gross, and 416 M. B. M. net. Table X summarizes the results.

TABLE X

SUMMARY OF TIME REQUIRED TO BUCK 346 CUTS BY HAND

Operation	Average Time per Tree—Minutes	Per cent of Total Time
Walking	.99	3.42
Preparing to work	.35	1.21
Swamping	3.60	12.40
Chopping	.63	2.17
Sawing	10.36	35.68
Wedging	1.01	3.49
Oiling Saw	.83	2.85
Gathering tools	.53	1.82
Resting	5.11	17.60
Filling oil bottle	.09	.30
Blocking up	.11	.39
Changing ax	.04	.13
Getting wedges	.27	.94
Changing sides	.06	.22
Preparing to undersaw	.12	.42
Adjusting undercutter	.13	.43
Looking over situation	.27	.99
Releasing saw	.02	.07
Tool sharpening, fitting	.14	.48
Looking for mark	.03	.12
Walking in and out	3.54	12.17
Non-classifiable	.78	2.70
Totals	29.01	100.00

As an inspection of the data revealed a marked variation between the different buckers a preliminary study was made to determine their relative efficiency, etc., the resulting figures being as follows: .88; 1.16; 1.20; .86; .88; (1.00 being the average of the five). These efficiency factors apply to the time of items varying with diameter only and is independent of the amount of time spent resting. They were used to bring the times of the individual workmen to a common standard before attempting to determine the influence of diameter.

The investigation then followed the lines already described. The items varying with diameter were in this case, "sawing," "chopping," "wedging," and "oiling"; the effect of diameter on these items, after graphic averaging, is given in the first two columns of Table XI. "Walking," "preparing to work," "gathering tools," and "swamping," which may obviously be treated as constant per cut, are found in Table X to total 5.5 minutes, and this amount is added to give column B of Table XI. The remaining items include 36.96% of the total time, and this amount is prorated in column C. The final column D, is obtained by dividing each value of column C by the scale of a 16-foot log of the corresponding diameter (Scribner, Dec. C log rule).

The use of 16-foot logs in computing this last column is to give results comparable to those which would have been obtained had all

the bucking been done by hand in the woods. It might at first appear that a serious inaccuracy is involved therein, on account of the fact that the workmen would have less walking to do between cuts in bucking short lengths than they had in the operations studied. It will be observed, however, in Table X, that "walking" only occupies 3.42% of the total time and as much of this is between trees, instead of between cuts, the possible savings therein must be relatively insignificant.

TABLE XI

TIME COST OF HAND BUCKING AS AFFECTED BY DIAMETER OF CUT

	Time per Tree—Minutes			
Diameter of Cut Inside Bark —Inches	A Sawing, chopping, wedging and oiling	B Same, plus walking, gathering tools, etc. (A+5.5)	C Same, corrected to prorate delays, etc. (B×1.586)	D Time per M. B. M. Gross Scale, 16 foot logs, Minutes
8	2.2	7.7	12.2	407.0
10	2.9	8.4	13.3	221.7
12	3.7	9.2	14.6	182.4
14	4.5	10.0	15.9	144.5
16	5.2	10.7	17.0	106.2
18	6.1	11.6	18.4	87.6
20	7.2	12.7	20.1	71.8
22	8.3	13.8	21.9	66.4
24	10.0	15.5	24.6	61.5
26	11.8	17.3	27.4	54.8
28	13.8	19.3	30.6	52.7
30	16.0	21.5	34.1	51.6
32	18.5	24.0	38.1	51.5
34	21.1	26.6	42.2	52.7
36	23.5	29.0	46.0	50.0
38	26.3	31.8	50.4	47.1
40	28.9	34.4	54.6	45.5
42	32.0	37.5	59.5	44.4
44	34.5	40.0	63.4	42.8
46	37.4	42.9	68.0	42.8
48	40.3	45.8	72.6	42.0
50	43.3	48.8	77.4	41.3
52	46.4	51.9	82.3	40.8
54	49.7	55.2	87.5	40.1
56	52.8	58.3	92.5	39.4

The final figures are moreover slightly artificial because of the use of the standard 16-foot log length. If they are to be compared with those of some other operation in which the logs average for example, 18 feet long, they should be reduced by multiplying them by 16/18. This will, of course, not disturb the relative costs of the different sizes.

Cost figures for long-length bucking are usually based on the entire scale of the long logs manufactured, rather than on the 16-foot section below each cut. It is useless to compute such figures, however, for logs of various top diameters, since the scale of a log of any given diameter is not a constant, but varies with its length. Such figures may, on the other hand, properly be based on tree diameter, and this has been done in Table XV, hereafter to be presented.

STEAM-SAW BUCKING

Studies were made of two steam saws, but on analysis, it was found that one of the saws was so inefficient that the values obtained therefrom were irregular and confusing, and of little value. The summary of the study of the saw which was functioning properly is given in Table XII, 233 cuts having been observed, with a scale of 173 M. B. M., gross.

TABLE XII

Summary of Time Required to Buck 233 Cuts by Steam Saw

Operation	Average Time per Cut—Minutes	Per cent of Total Time
Waiting for swing donkey	3.02	61.47
Spotting	.18	3.60
Releasing choker	.24	4.96
Setting dogs	.19	3.87
Sawing	.94	19.19
Releasing saw	.21	4.21
Looking for mark	.01	.17
Landing delay	.06	1.31
Lining up saw	.01	.29
Engine trouble	.01	.12
Saw trouble	.01	.25
Chute trouble	.01	.27
Out of chute	.01	.15
Stopping to wedge	.01	.06
Miscellaneous	.01	.08
Totals	4.92	100.00

Of these cuts 190 were in western yellow pine and these only were used in studying the effect of diameter on time. The time items affected by diameter were in this case "spotting," "setting dogs," "sawing," "releasing saw," "looking for mark," "lining up saw," and "stopping to wedge." The remaining items, amounting to 68.61% of the total, are all of the sort which should be prorated. Table XIII shows the resulting figures. The values in column B have been graphically averaged, and those of the final column have been slightly adjusted to eliminate an irregularity which resulted from the irregular progressions of the Scribner rule.

TABLE XIII

TIME COST OF STEAM SAW BUCKING AS AFFECTED BY DIAMETER OF CUT

A Diameter of Cut Inside Bark —Inches	B Time of Items Dependent on Diameter— Minutes per cut	C Time, all items B×3.14 Minutes per cut	D Time per M. B. M. Gross Scale, 16 foot Logs—Minutes
12	.8	2.4	.30
13	.8	2.5	.26
14	.8	2.5	.23
15	.8	2.6	.20
16	.9	2.7	.17
17	.9	2.8	.16
18	.9	3.0	.14
19	1.0	3.1	.13
20	1.0	3.3	.12
21	1.1	3.6	.12
22	1.2	3.8	.11
23	1.3	4.0	.11
24	1.4	4.3	.11
25	1.5	4.6	.10
26	1.6	4.9	.10
27	1.7	5.3	.10
28	1.8	5.6	.09
29	1.9	5.9	.09
30	2.0	6.3	.09
31	2.1	6.7	.09
32	2.2	7.1	.09
33	2.4	7.6	.10
34	2.5	8.1	.10
35	2.7	8.6	.10
36	2.9	9.3	.11
37	3.1	9.9	.11
38	3.3	10.6	.12

Bucking of Trees by Combination of Two Methods

The foregoing tables show the time cost of bucking logs of various diameters, and it now remains to investigate the bucking cost for trees of various diameters. This will depend in part on the height and form of the trees of each diameter class, and in part on the relative amounts of bucking done by hand and left to the steam saw. It is therefore impossible to arrive at figures which are universally applicable, but it is possible to work out conclusions reasonably accurate for the logging operation studied.

TABLE XIV

TIME COST OF BUCKING, PART IN WOODS BY HAND, AND PART ON LANDING BY STEAM SAW, AS AFFECTED BY TREE DIAMETER

Diameter Breast High—Inches	Average Height Logs	Diameter Inside Bark—Inches, of Logs Bucked in Woods	Diameter Inside Bark—Inches, of Logs Bucked in Chute	Gross Scale Scribner D. C. Feet B. M.	Time—Minutes Woods	Time—Minutes Chute	Time per M. B. M. gross scale—Minutes Woods	Time per M. B. M. gross scale—Minutes Chute
18	3	8		32	12.2			
			12	79		2.4		
			14	114		2.6		
				225	12.2	5.0	54.2	22.2
20	3	9		40	12.7			
			13	97		2.5		
			15	142		2.6		
				279	12.7	5.1	45.5	18.3
22	4	9		40	12.7			
			13	97		2.5		
			15	142		2 6		
			17	185		2.9		
				464	12.7	8.0	27.4	17.2
24	4	9		40	12.7			
			14	114		2.6		
			16	159		2.7		
			18	213		3.0		
				526	12.7	8.3	24.1	15.8
26	4	9		40	12.7			
			14	114		2.5		
			18	213		3.0		
			20	280		3.3		
				647	12.7	8.8	19.6	13.6
28	5	9		40	12.7			
			15	142		2.6		
			18	213		3.0		
			20	280		3.3		
			22	334		3.8		
				1009	12.7	12.7	12.6	12.6
30	5	9		40	12.7			
			16	159		2.7		
			19	240		3.2		
			22	334		3.8		
			23	377		4.0		
				1150	12.7	13.7	11.0	11.9
32	5	10		50	13.3			
			17	185		2.8		
			20	280		3.3		
			23	377		4.0		
			25	459		4.6		
				1351	13.3	14.7	9.8	10.9
34	6	9		40	12.7			
			16	159		2.7		
			21	304		3.6		
		23		377	23.2			
			26	500		4.9		
			27	548		5.3		
				1928	35.9	16.5	18.6	8.6

TABLE XIV—(*Concluded*)

Diameter Breast High—Inches	Average Height Logs	Diameter Inside Bark—Inches, of Logs Bucked in Woods	Diameter Inside Bark—Inches, of Logs Bucked in Chute	Gross Scale Scribner D. C. Feet B. M.	Time—Minutes Woods	Time—Minutes Chute	Time per M. B. M. gross scale—Minutes Woods	Time per M. B. M. gross scale—Minutes Chute
36	6	9		40	12.7			
			17	185		2.8		
			22	334		3.8		
		25		459	26.0			
			27	548		5.3		
			29	609		5.9		
				2175	38.7	17.8	17.8	8.2
38	6	10		50	13.3			
			18	213		3.0		
			23	377		4.0		
		26		500	27.4			
			28	582		5.6		
			31	710		6.7		
				2432	40.7	19.3	16.7	7.0
40	6	10		50	13.3			
			19	240		3.1		
			24	404		4.3		
		27		548	28.9			
			30	657		6.3		
			32	736		7.1		
				2635	42.2	20.8	16 0	7.9
42	6	10		50	13.3			
			20	280		3.3		
			25	459		4.6		
		29		609	32.3			
			31	710		6.7		
			34	800		8.1		
				2908	45.6	22.7	15.7	7.8
44	7	10		50	13.3			
			19	240		3.1		
			25	459		4.6		
			29	609		5.9		
			32	736		7.1		
		34		800	42.2			
			36	923		9.3		
				3817	55.5	30.0	14.5	7.9
46	7	11		65	13.9			
			20	280		3.3		
			26	500		4.9		
		30		657	34.1			
			33	784		7.6		
		36		923	46.0			
			38	1068		10.6		
				4277	94.0	26.4	22.0	6.2
48	7	11		65	13.9			
			21	304		3.6		
			27	548		5.3		
		31		710	36.1			
			35	876		8.6		
		37		1029	48.2			
			39	1120		11.4		
				4652	98.2	28.9	21.1	6.2

Table XIV gives the computations involved. Column 1 and 2 are derived from the height-diameter study already described (page 323). The values of columns 3 and 4 are taken from the standard taper table for western yellow pine of the U. S. Forest Service. This table is not exactly applicable to the type of timber which was studied, but since any differences will tend to modify both the diameters cut and the volumes produced in the same direction, it can be used here without serious error. A careful study of the data showed that it was customary for the buckers in the woods to saw a single top cut for trees up to and including 32 inches in diameter, to divide into two logs trees from 34 to 44 inches, inclusive, and to divide into 3 logs all larger trees. (This represents the average practice only and was not followed at all rigidly.) The values were assigned to Column 3 or 4 to agree with this procedure. Column 5 gives the scale of the logs and of the trees. Columns 6 and 7 give the time required to make the various cuts, their values being taken from column D of Table XI, and column D of Table XIII, respectively. The final columns, 8 and 9, are columns 6 and 7, respectively, divided by column 5, and with the decimal point shifted to express the results in terms of thousands of feet B. M.

From the final columns, column 5 of the original Table I (p. 318) was derived by allowing for cull, multiplying by the proper cost of a minute's time, and graphically adjusting slight irregularities.

GENERAL CONSIDERATIONS AND CONCLUSIONS

The foregoing tables have been presented at length not only to support the conclusion stated on page 317, but also because it is felt that there is much information therein which may prove of value to lumbermen who are studying the details of their operations with a view to increased efficiency. Physical conditions vary widely between the several lumbering regions of the state and even between different logging units of a single operation, and it is therefore futile to hope for figures of exact applicability everywhere. It has been found, however, that analyzed figures on details will often apply where totals will not. For example, the time required to fall a tree of a given diameter was substantially the same on the different operations studied, but the cost per M. B. M. varied widely on account of the variation in height and volume between trees of the same diameter; that is, Table XIV, would not apply well to regions where the timber is very tall, but it would be relatively easy to construct from the detailed figures previously presented a similar table which would be approximately correct for any known conditions.

Throughout this study unessential refinements have been avoided, and the highest degree of simplicity consistent with reliable results has been sought. In some instances slight inaccuracies have been accepted as preferable to complexity, but only where it could be clearly seen that they were of negligible importance.

It is of interest to consider the probable causes which underlie the high cost per M. B. M. of manufacturing small logs. These are three in number:

1. The Scribner log rule (as well as the Spaulding) is ultra-conservative in the values assigned to small logs; whereas an overrun of 6% is to be expected for 48-inch trees, as much as 24% should be obtained from 18-inch trees. Were the results of Table I expressed in terms of lumber tally instead of log scale, therefore, the cost of log making from the smallest size tree would be only 2½ times instead of three times that from the largest.

2. The yield in lumber per cubic foot of actual volume is relatively smaller for small logs than for large on account of the larger percentage of waste involved in sawing lumber therefrom. Costs per cubic foot of volume would be less unfavorable to the smaller sizes, and on this basis the ratio between the costs of 18- and 48-inch trees is further reduced to 1¾ to 1. This fact has obviously little practical significance, however, in connection with present-day manufacturing methods.

3. The remaining important factor is the large amount of time which must be spent on every tree and on every log regardless of its size and which, in the case of small trees, must be charged against the small volume obtainable.

In conclusion, it is not intended to point a moral with these figures. They are, in themselves, striking, and suggest many lines of thought and further investigation. In particular the question arises as to whether, in the subsequent handling of the logs, both in the woods and in the sawmill, the same relatively high costs will apply to the product of the smaller trees. The relative value of the lumber product of large and small trees is also a point at issue. Data have already been gathered on some phases of these questions which will be published at a later date.

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